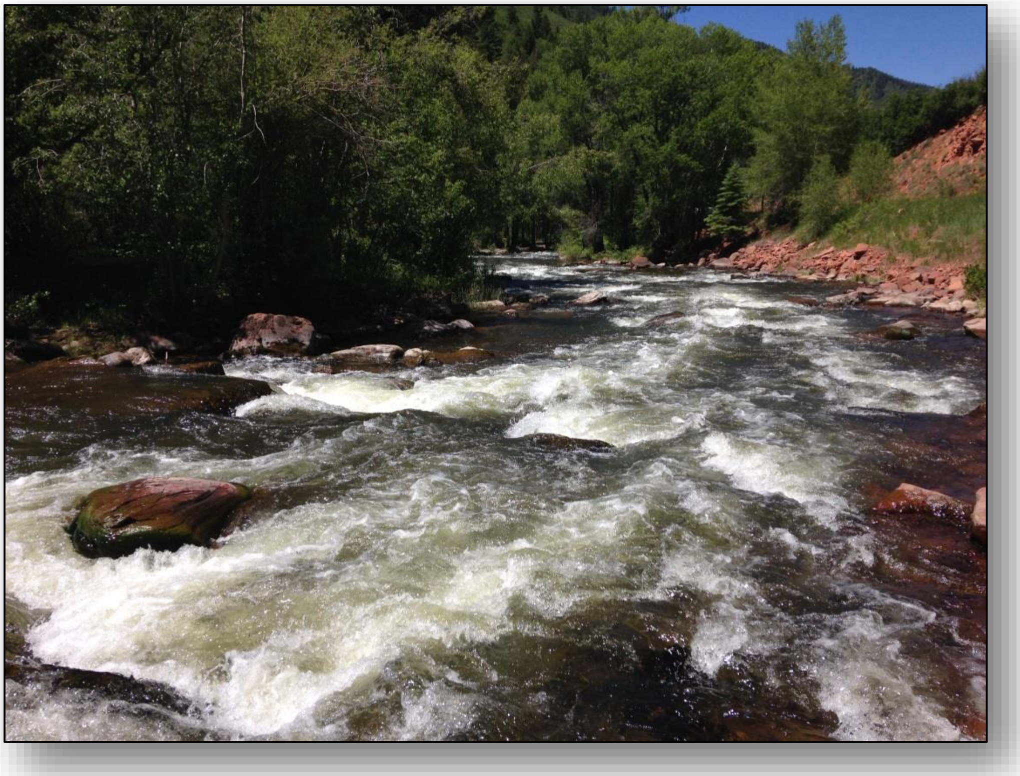
DIDYMO SURVEY, LOWER FRYINGPAN RIVER, BASALT, COLORADO

2014



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FRYINGPAN RIVER DIDYMO ANALYSIS

Contents

Executive Summary

Didymosphenia geminata, commonly referred to as “didymo” or “rock snot,” is a freshwater diatom, a type of algae that lives in streams attached to rocks and other substrates. Didymo has been present in North America for over 10,000 years and there is strong evidence that there were blooms prior to any human activity (Card, 2014). Preliminary calculations show that approximately 20 percent of Colorado mountain streams may contain didymo (Spaulding, 2007). The ability for didymo to be prolific was correlated to flow regimes of dam-influenced river systems (Spaulding, 2007). The impact of didymo on the Gold Medal fishery in the Lower Fryingpan River is currently unknown. This project analyzed the presence or absence of didymo including spatial and temporal variability, and water quality throughout the Lower Fryingpan River, from immediately below the Ruedi Reservoir dam to the confluence with the Roaring Fork. Potential management strategies for reducing the occurrence and persistence of didymo were also identified.

Results from year one of this study revealed a significant decrease in didymo after the high flow event (peak 700 cfs) in 2014. The decrease could be attributed to the scour effect from bedload migration. When compared to reference sites (upstream of Ruedi Reservoir and at the inlet), there was no visual evidence of didymo cover but presence was detected through microscopic analysis. Moving forward, more data is needed to fully understand the effect of flow regimes and the seasonality of didymo.

Results from a study of Colorado’s rivers indicate that high densities of didymo were related to a decline in total macroinvertebrate richness (Spaulding, 2007). Studies on the effects of didymo on fish are too recent with limited data (2-3 years) to determine any trends in the fish population. Fish that consume benthic prey and nest beneath or between cobbles could be most impacted because they utilize the same habitat as didymo (Larned et al., 2006). Given large amounts of non-nutritious stalk material present on stream substrate, didymo is predicted to have a deleterious effect on native fish (Spaulding, 2007).

There is much uncertainty around why and how didymo is spreading and reaching nuisance levels. The mechanisms driving the spread of didymo cannot be explained just by human transport, as didymo is being found in remote, hard to access areas of the world such as New Zealand, Colorado, and Chile (Spaulding, 2007). Some scientists speculate climate change could be causing didymo to bloom in new places on a global scale. It is not realistic or feasible for water managers of the Fryingpan River to minimize causes of climate change. It is more realistic to acknowledge and manage the impact of humans on the spread of didymo. Fishermen and other water users carry didymo from one body of water or reach of stream to another on their boots, waders, boats and/or tackle. At this time, the most feasible control of the spread of didymo is containment through educating the public on the importance of cleaning gear. A public awareness campaign, including signage and gear wash stations located in popular fishing areas could reduce the probability of the transfer of didymo to clean waters.

ROARING FORK CONSERVANCY

Introduction

The Lower Fryingpan River has a high level of water quality, is an important Gold Medal Fishery, and is the water supply for thousands of downstream users. The Lower Fryingpan River is defined in this study as immediately downstream of Ruedi Reservoir to the confluence with the Roaring Fork River near Basalt. This section of the Fryingpan River (14 miles) within the Roaring Fork watershed is included in one of the longest contiguous sections of Gold Medal water in the state of Colorado. The publically accessible portion of the Lower Fryingpan River contributes an estimated $1.8 million annually to the Town of Basalt's economy (Crandall, 2002).

Didymosphenia geminata, commonly referred to as "didymo," is a freshwater diatom, a type of algae that lives attached to rocks and other substrates on the bottom of streams. Didymo has been present in North America for over 10,000 years and there is strong evidence that there were blooms prior to any human activity (Card, 2014). Preliminary calculations show that approximately 20 percent (plus or minus 13 percent) of Colorado mountain streams are estimated to contain didymo (Spaulding, 2007). These estimates are based on presence of cells, not on formation of nuisance blooms. The actual presence is expected to be greater than the preliminary estimates.

Didymo is the only freshwater diatom to exhibit large scale invasive behavior and is a persistent phenomenon on a global scale. There is a growing body of evidence that suggests didymo is expanding its ecological range and tolerance. This is a species with the biological capacity to produce inordinate amounts of stalk material. Didymo produces thick mats that clog stream habitat for aquatic plants and macroinvertebrates.

The impact of didymo on the Gold Medal fishery in the Lower Fryingpan River and subsequently the Roaring Fork River is currently unknown. The ability for didymo to be prolific has been correlated to flow regimes of dam-influenced river systems (Spaulding, 2007). The Lower Fryingpan River is dam controlled at Ruedi Reservoir. Didymo thrives in sustained low flow conditions and is mobilized during high flows with associated bed load migration.

The presence and seasonality of didymo throughout much of the small tributaries in Colorado and specifically the Lower Fryingpan River has not been studied. This project can assist and provide river users and water-quality managers with valuable data and to help identify management strategies for mitigation.

Objectives

The project analyzes the presence or absence of didymo throughout the Lower Fryingpan River from immediately below the Ruedi Reservoir dam to the confluence with the Roaring Fork. The objectives are:

1. To measure the presence or absence and size of the colony of didymo throughout the study reach
2. To measure water quality parameters, specifically pH, temperature, dissolved oxygen, and specific conductance at each didymo sampling location
3. To identify the spatial and temporal variability of didymo in the reach
4. To identify potential management strategies for reducing the occurrence and persistence of didymo

Methodology

Selection of Sampling Sites

Sites were selected using a stratified approach at every 0.7 miles of river using ArcGIS. Where sites were close to bridges and had more accessible parking and road access, the sites selection was minimally modified. The length of each sampling site was identified as 10 times the width of the stream at that location (Appendix I).

Table 1. Site locations on the Fryingpan River. Site 1 is the most downstream site, Site 20 is closest to Ruedi Reservoir

Site #	Latitude	Longitude	Elevation (meters)	Average width of river (meters)
Site 1	4359737.27	325111.76	2026.38	18.30
Site 2	4360342.87	326247.01	2053.35	15.55
Site 3	4360275.03	327171.40	2080.21	13.72
Site 4	4360131.45	328129.99	2075.98	22.87
Site 5	4360310.63	328894.53	2097.16	22.87
Site 6	4360565.22	330038.83	2116.96	24.70
Site 7	4360759.15	330970.15	2118.50	13.72
Site 8	4360835.73	332129.37	2132.95	27.45
Site 9	4360373.15	332750.36	2154.66	22.87
Site 10	4360555.00	333830.00	2171.66	13.72
Site 11	4360716.83	334505.54	2156.88	27.45
Site 12	4360439.50	335477.03	2165.46	22.87
Site 13	4360326.35	336348.41	2171.99	13.72
Site 14	4360421.28	337319.98	2191.78	22.87
Site 15	4360082.71	338490.97	2220.00	18.30
Site 16	4359409.83	339213.60	2233.73	18.30
Site 17	4359351.64	340494.25	2251.38	25.62
Site 18	4358936.70	340964.26	2245.92	13.72
Site 19	4358541.00	341676.33	2274.41	22.87
Site 20	4358854.93	342890.30	2286.95	41.17

Sampling procedure

1. The collection of didymo samples used the field based rapid periphyton survey EPA approved protocol at 20 sites (unless restricted access) throughout the study reach (14 miles). Sampling occurred three times in 2014 (May, June, and October). The June sample was after the high flow event. This allowed for the didymo bloom to reestablish on any rocks that had been scoured during the high flow event.
2. Each sampling site was identified as 10 times the width of the stream at that location. The presence of didymo was identified at each site using a gridded viewing bucket at 5 locations within the sample site and recorded on the rapid periphyton survey field sheet. Cobbles from riffles and runs were sampled at each site. The cobbles were scraped and preserved for microscopic analysis in the laboratory. A rock from each of the viewing bucket locations was collected, scraped, and the area measured with aluminum foil. If there was less than 5% cover of the rock surface with algae or didymo, the rock was not sampled.
3. The foil was brought back to the laboratory and weighed and converted to a surface area. The algae sample was dried, weighed, and burned in a furnace to measure the mass of organic content, presumably didymo.
4. Simultaneous collection of water quality data (pH, specific conductance, temperature, and dissolved oxygen) was conducted using a YSI in-situ sensor was measured at the 20 sampling locations.
5. Microscopic analysis of the samples was performed using a compound microscope at 100x power.
6. Creation of an Arc-GIS map of didymo occurrence.
7. Production of a final report.

Samples were collected at 20 sites on the Fryingpan River on May 19-21, June 18-20, and October 17-18 2014. The Fryingpan river sites were montane (approximately 2,000-2,300 m). Sampling was performed at locations in which the river was accessible on foot. The location (right bank, left bank, or middle) was recorded at each sampling location. Five rocks from each site were randomly chosen and an aggregation of scrapings from the rocks was used for analysis. The reason for this approach is high spatial variation among samples from different rocks at the same site. The scrapings were bottled and chilled to 4 degrees Celsius and returned to the CMC laboratory for microscopic examination.

Figure 1. Student observing didymo coverage with a gridded viewing bucket

Results

Raw data is presented in Appendix II.

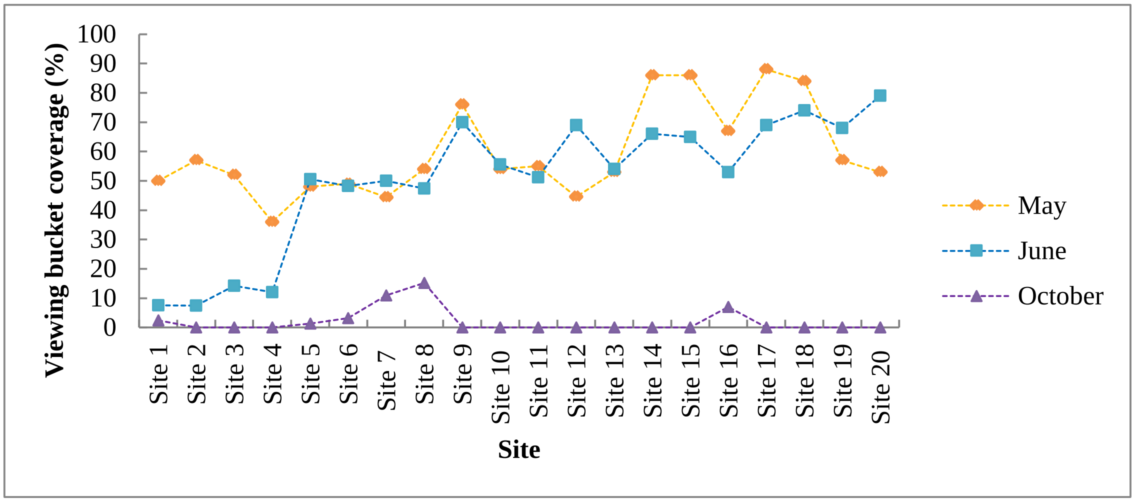

Figure 2. Didymo coverage with viewing bucket during May, June, and October sampling event

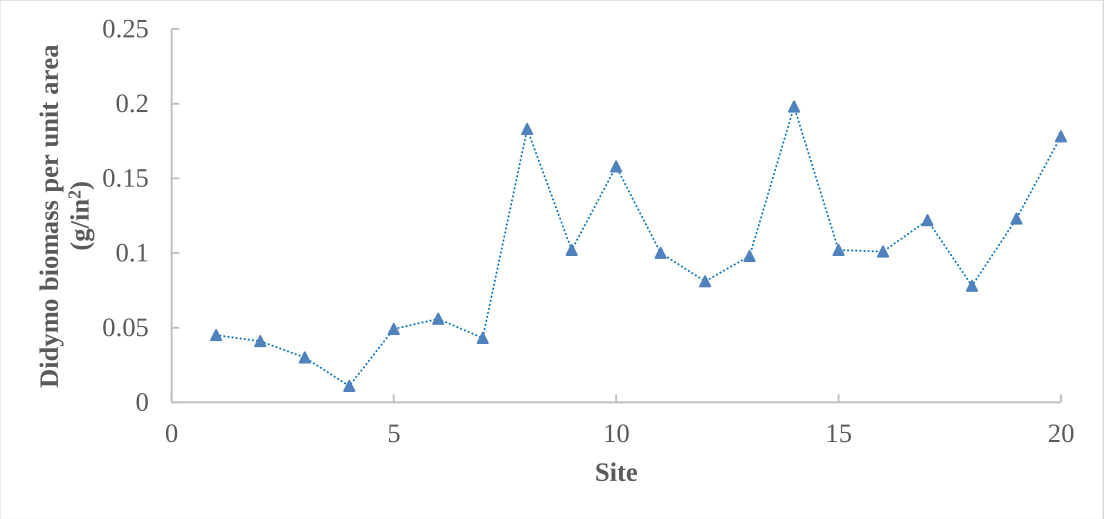

Figure 3. Didymo biomass grams/square inch from June 2014 sampling event

Discussion

Presence of didymo in the Fryingpan River

During the May and June sampling events, the predominant algae present was didymo. The May sampling event was prior to sustained increased releases from Ruedi Reservoir of greater than approximately 400 cubic feet per second (cfs) for over 12 continuous days. The peak flows reached over 700cfs. There was a significant decrease in didymo cover between the May and June sampling event at 9 sites. Four of these sites are at downstream locations where there is a more cobble streambed. The decrease could be attributed to the scour effect of high flows and bedload migration. The best hydrological predictor of didymo biomass is number of days since a significant flow event (Spaulding report, 2008). Large floods scour the riverbed and return biomass to a low level. Floods must be high enough to cause the rocks on the streambed to mobilize, scouring the cells from rock surfaces (Larned, 2006). In North America and Europe, high density blooms are frequent in rivers directly below impoundments (Kawecka and Sanecki, 2003). A monthly survey of rivers in Alberta, Canada suggests that didymo occurs with higher frequency in locations where flow and temperature are regulated by dams compared to non-regulated rivers (Spaulding, 2007). In these dam regulated reaches, stable flows and fairly constant temperatures favor development of large masses of didymo. Restoration of historic, or pre-impoundment, natural flows in rivers may mitigate nuisance blooms, as well as restore river condition.

There was considerably more didymo in oxygenated slower moving water along the streambanks in comparison to oxygenated fast moving water in the thalweg. Upon inspection of small ponds along the banks of the Fryingpan River, there was no significant occurrence of didymo in the ponds. One private landowner did request a sample to be taken from his pond. Microscopic analysis confirmed there was didymo in the sample. The landowner had removed thick mats of didymo from the pond filtration system.

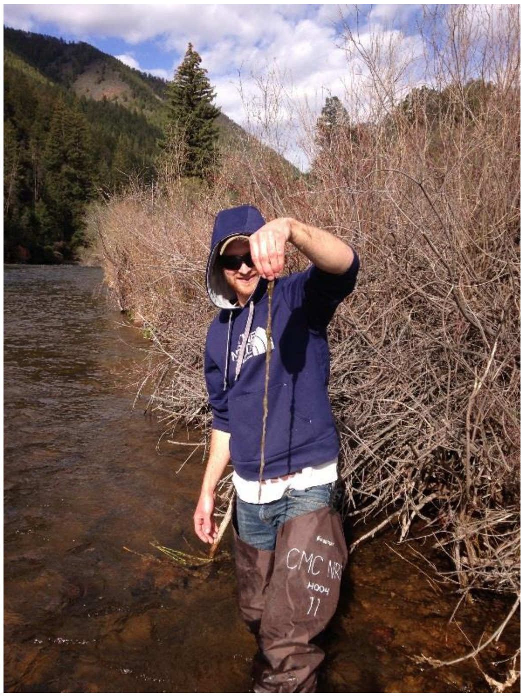

Figure 4. Didymo stalk found attached to a stick on the streambed, during sampling event in May 2014

When compared to reference sites (upstream of Ruedi Reservoir and at the inlet), there was no visual evidence (using the viewing bucket) of didymo cover present during the May and June sampling events. When microscopically analyzed, didymo was present at all the background sites. It is not a concern that didymo is present at the reference sites because it is native to Colorado was not found at nuisance concentrations at these sites. During the October sampling event, an increase in didymo cover was observed at the inlet to Ruedi Reservoir. The increase in didymo cover was not as extensive as the didymo cover at sites downstream of Ruedi Reservoir during May or June sampling events.

The mass of didymo per unit area (grams/square inch) was measured during the June sampling event. It was intended to be measured during the October sampling event but there was not enough didymo present to warrant measurements. The green algae in the sample and resulting dry ash weight would have produced errors and exceeded actual didymo mass values.

Figure 5. Left photo didymo with thick mat coverage in May 2014. Right photo didymo very low coverage in October 2014

During the October sampling event, the predominant algae present was a green or blue-green algae (species unknown). There was significantly less didymo throughout the entire river compared to the May and June sampling events. It is unknown exactly why there was a decrease in didymo cover but it could be attributed to the temporal variation of didymo growth. There are no published articles about the seasonal variability of didymo in Colorado. There are, however, a limited number of published articles about the temporal changes of algae in alpine and montane environments in Colorado. For example, at alpine sites on the Snake River near Loveland Pass, green algae were found to increase in September and October to 70% from 5% in August (Vavilova and Lewis, 1999). Sarah Spaulding, a diatom expert with the USGS confirmed that there is a lack of research on the temporal variation of didymo in Colorado (oral communication). She was interested in this study and wanted to be kept informed of future work.

Didymo blooms are unlike those of other algae. While many blooms are a result of an increase in cellular biomass, didymo blooms are formed of carbohydrate-based stalks (Card, 2014). The stalks are an attempt to gain nutrients. The mats and tufts along the streambed might appear as though the didymo is thriving but this isn’t necessarily true. The mechanisms driving the spread of didymo cannot be explained just by human transport, as didymo is showing up in remote, hard to access areas of the world such as New Zealand, Colorado, and Chile (Spaulding, 2007). Some scientists think climate change could be a driver that is causing didymo to bloom in new places on a global scale. There is now evidence from various areas around the world where blooms and year to year variation is linked to variation in climate. Another unresolved question is whether there is more than one genotype of didymo. There could be a different or new genetic strain that blooms under variable climatic circumstances and is leading to the increase and spread of didymo.

Microscopic analysis

Didymo cells were present in all microscopic analysis of sites on the Fryingpan River and at the reference sites. There was no evidence of didymo in Rocky Fork or Frenchman Creek. It was more challenging to locate didymo cells at both reference sites and Fryingpan sites during the October sampling event. When there was noticeably less didymo in the river, it was also more challenging to identify didymo cells during the microscopic analysis.

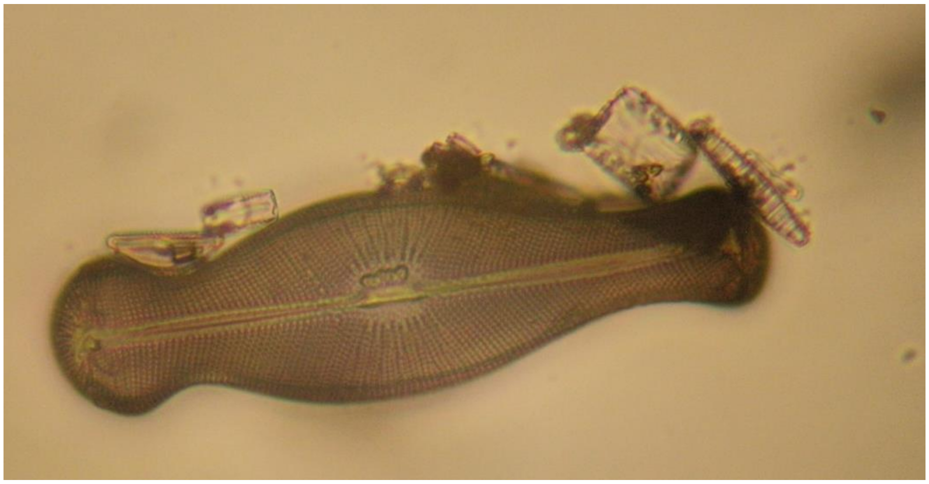

Figure 6. Didymo cellular structure from the lower Fryingpan River at site 18 from June 2014 sampling event.

Water quantity and water chemistry

Preliminary data from a random survey of streams in the western United States show that didymo is present in a wide range of freshwater conditions (Stoddard and others, 2005). As of 2011, didymo can be found in 19 U.S. states, in fast or slow moving streams, streams with either high or low nutrient levels, and in shallow or deep water. Large blooms are most commonly found below dams where water temperatures and flows are more stable (Spaulding, 2007). Temperature, pH, conductivity, and dissolved oxygen values were measured at each sampling site. The full extent to which these parameters effect didymo is largely unknown and specific from river to river. Significant volumes of didymo can alter the water chemistry in the river. Didymo has a greater presence in low temperature waters but has been found in temperatures ranging from 0.1°C to 27°C (Whitton et al 2009). Didymo prefers a pH between 6.4 and 9.0 but can survive in pH levels between 4.0 and 9.5 (Kilroy et al. 2006).

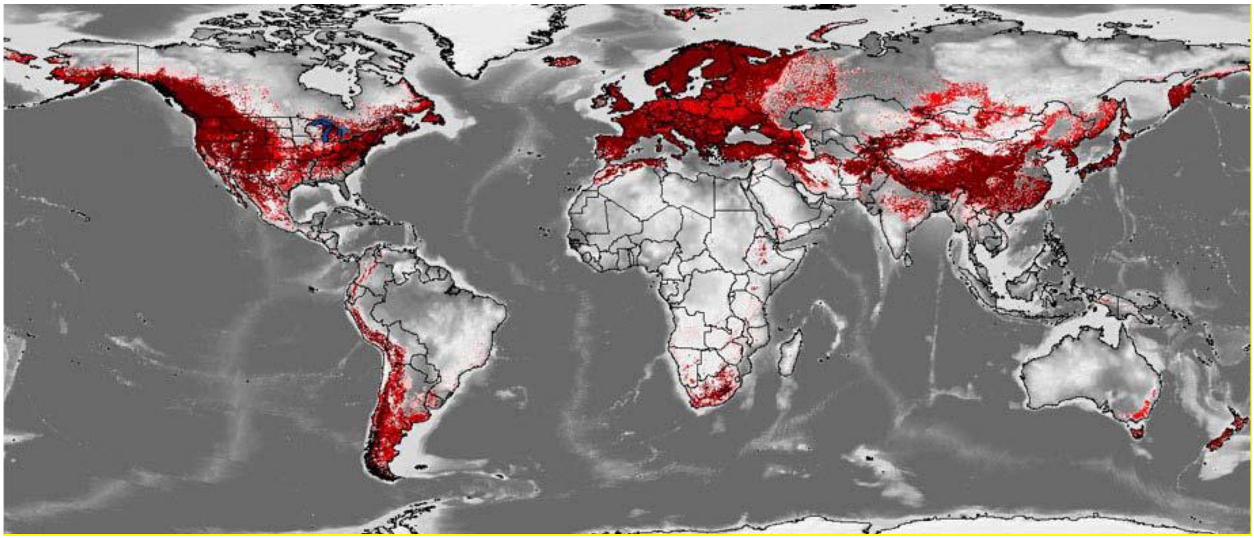

Figure 7. Map of the world showing regions where suitable stream habitats for *D. geminata* are located. Results for Australia are preliminary (Map by Kris McNyset, US Environmental Protection Agency).

In Iceland, one study of didymo presence, found no relation to bedrock geology or specific conductance, that is, the distribution and biomass of extensive mats appeared to be unrelated to water chemistry (Jonsson, 2000). Data from an EPA study concluded that didymo has a wide range of specific conductance tolerance (0-650 umho/cm) from electrolyte poor to concentrated waters, although there was greater occurrence of didymo at lower concentrations of conductance (EPA EMAP Western Pilot 2000-2003, 2003).

Didymo can be found in both high-nutrient and oligotrophic waters. Rivers in Poland where didymo formed large masses had concentrations of nitrate ranging from 1.7 to 3.8 mg/L and phosphate ranging from 13 to 100 ug/L (Kawecka & Sanecki, 2003). The discovery of nuisance didymo populations in high nutrient waters was the first recognition that the species was appearing outside its recognized ecological range. This has led to a more likely explanation that didymo blooms are the result of large-scale human intervention in climate, atmospheric, and edaphic processes that favor this species (Bothwell, 2014). In low nutrient waters with low phosphorous (below 2 ppb), phosphorous is assumed to be the cause of the bloom formation (Bothwell, 2014). In a report studying oligotrophic streams (Sundareshwar, 2011), algal biomass was researched under low phosphorus conditions. This report concluded that a bloom which consists primarily of stalk material only forms in low phosphorous conditions. Typically aquatic biologists associate increased nutrients associate with higher algal biomass, but this is not necessarily true for didymo.

Didymo can alter the diversity and distribution of macroinvertebrates. A recent study has found that the proportion of larger sized macroinvertebrates such as mayfly, stonefly, and caddisfly decline in waters where didymo is present while the proportion of smaller invertebrates such as midges and worms increase (Gillis, 2009). As a result, the overall population of macroinvertebrates may not change, but a shift in the proportion of larger to smaller invertebrates could alter the fish populations present in a given stream.

Results from a study of Colorado's rivers indicate that high densities of didymo were related to a decline in total macroinvertebrate richness (Spaulding, 2007). In these rivers, the macroinvertebrate community was dominated by chironomids (midge fly larvae). Analysis of macroinvertebrate gut contents showed that mayfly, stonefly, caddisfly, and chironomid larvae consumed didymo, but that the presence of didymo in guts was related to body size. The results suggest that small macroinvertebrates were not able to consume didymo. In didymo-affected sampling sites, ephemeroptera, plechoptera, and trichoptera (EPT) populations were found to have decreased while chronomid proportions increased (Gillis, 2009). Macroinvertebrate species that require exposed sediment are expected to be negatively impacted by extensive coverage of didymo (Spaulding, 2007). Research suggests that the impact of didymo on aquatic macroinvertebrates is directly related to temporal and spatial extent of nuisance blooms.

Studies on the effects of didymo on fish are recent and there is limited data available (2-3 years). More data is needed over a longer time period to determine any trends in the fish population. Fish that consume benthic prey and nest beneath or between cobbles could be most impacted because they utilize the same habitat as didymo (Larned et al., 2006). Given large amounts of non-nutritious stalk material present on stream substrate, didymo is predicted to have a deleterious effect on native fish (Spaulding, 2007). Furthermore, didymo blooms support the tubifex worm which is the only host of the fish parasite that causes whirling disease (Card, 2014).

Recommendations

Long term monitoring of didymo on the Fryingpan River

Monitoring the presence of didymo on the Fryingpan River should continue into the future. A recommended sampling schedule of 3 times per year (pre-high flow, post-high flow, and fall) at a reduced number of sites would allow for continued characterization of didymo. Sampling should include the background sites (above Ruedi Reservoir) to help identify if changes are occurring at the non-impacted sites. Included in this sampling should be water chemistry measurements (pH, temperature, specific conductance, and dissolved oxygen), cover estimates (with gridded viewing bucket), and biomass samples at each site. Other water quality parameters such as nutrients and metals can be added to the monitoring plan if water managers determine there is need to understand if a relationship exists between specific constituents and didymo. Several years (5 or more) of data collection will allow water managers to determine if there are statistically significant changes in didymo blooms.

Management and control of the spread of didymo

There is much uncertainty around why and how didymo is spreading and reaching nuisance levels. As mentioned above (page 8) the mechanisms driving the spread of didymo cannot be explained just by human transport, as didymo is showing up in remote, hard to access areas of the world such as New Zealand, Colorado, and Chile (Spaulding, 2007). For the purposes of this report it is not realistic or feasible for water managers of the Fryingpan River to minimize the drivers of climate change. It is more realistic to acknowledge and manage the impact of humans on the spread of didymo. Humans are mainly responsible for the spread of didymo beyond its historical range (Root and O’Reilly, 2012). Fishermen and other water users carry it from one body of water to another on their boots, waders, and tackle. The most feasible control of the spread of didymo is containment through educating the public on the importance of cleaning gear. A public awareness campaign, including signage and gear wash stations located in popular fishing areas could reduce the probability of the transfer of didymo to clean waters. An awareness campaign can be designed so that it educates water users to take personal responsibility for reducing the spread, collecting information on impacts, and identifying tools to support management decisions and responses. Because didymo is not always visible there is a general lack of information and knowledge available to water users. There is a need for further research to determine if the increase of flows from Ruedi Reservoir would decrease the presence of didymo. Other management strategies include the use of biocides, chelated copper, and musinex (Larned, 2006). All of which are generally not feasible on a large scale and can be detrimental to macroinvertebrate and fish populations.

Many communities throughout Colorado rely on tourism dollars that are generated by outdoor recreation. Natural resource opportunities like fly fishing represent an important economic value, yet they may be vulnerable to damage by the spread of nuisance species. In the United States, the cost to control and eradicate nuisance and invasive species is estimated at $120 billion annually, with one billion dollars from the impacts of invasive zebra mussels (Pimentel, 2005). Upon the appearance of didymo in New Zealand in October 2004, Biosecurity New Zealand initiated a national incursion response based on the potential losses to the national economy (Branson, 2006). The economic impact was estimated to be between $57 and $285 million New Zealand dollars, over a period of eight years.

An aggressive education and outreach program is required to change water user behavior in order to minimize spread of didymo on a global scale. A public awareness campaign, directed at water managers, scientists, freshwater anglers, boaters, guides, and other recreationalists must be integrated with existing invasive species programs.

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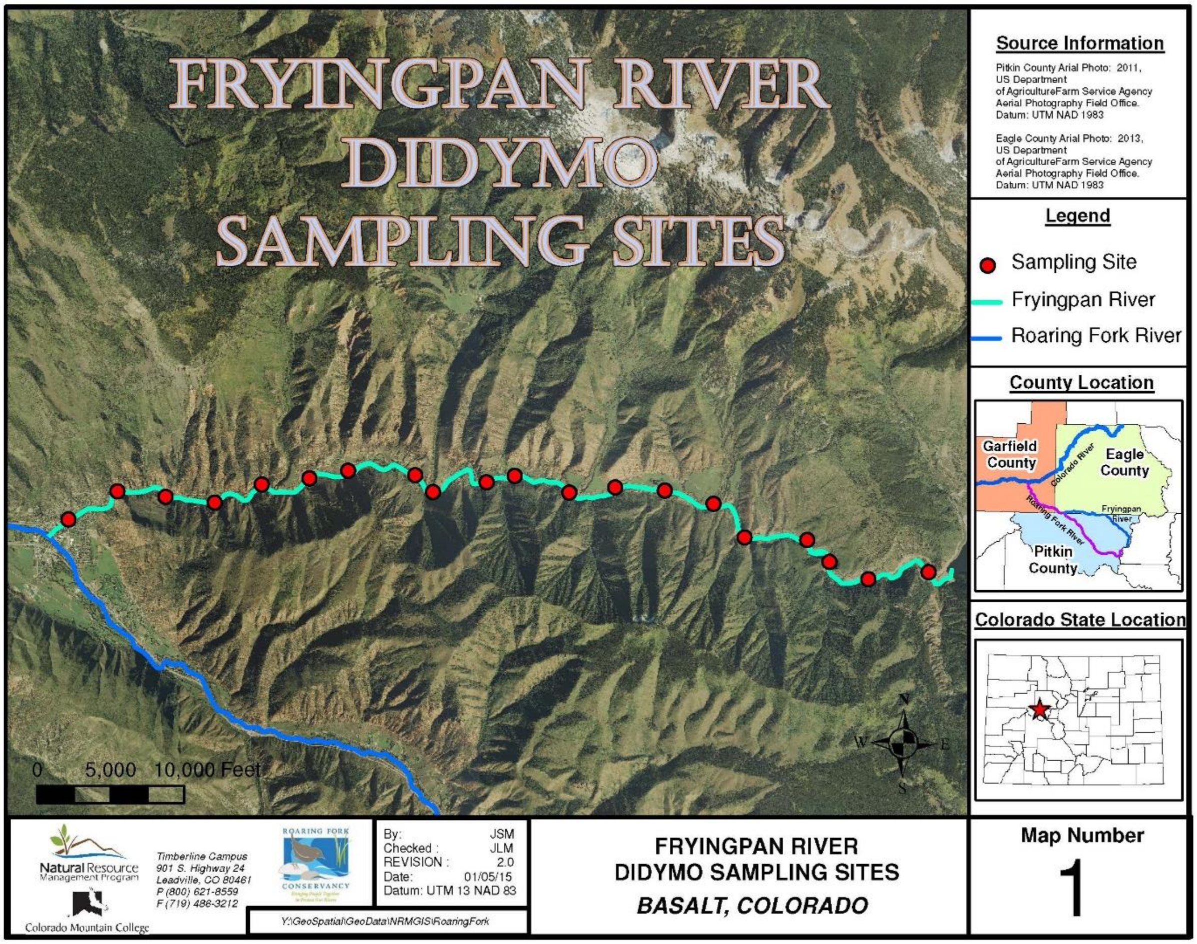
Appendix I. Map of Study Area



Appendix II. Raw Data

Table 1. Temperature data (degrees C) on the Fryingpan River on May, June, Oct

Site #	Time	Temp Event 1	Time	Temp Event 2	Time	Temp Event 3
Site 1	14:45	11.5	12:25	9.7	10:00	6.3
Site 2	15:25	12.1	13:40	10	11:15	6.5
Site 3	16:15	12.3	14:25	10.3	11:45	6.8
Site 4	9:05	4.8	15:35	10.6	12:00	7.2
Site 5	10:00	5.5	16:05	10.4	12:30	7.7
Site 6	10:50	6.6	9:00	5.8	13:20	9
Site 7	12:20	8.3	10:00	6.8	14:05	9.7
Site 8	13:00	9.1	10:40	12.1	14:50	10
Site 9	13:30	9.8	16:00	12.1	15:45	10.3
Site 10	14:00	10.1	16:43	11.6	16:25	10.2
Site 11	14:50	10	9:05	5.7	9:25	6.2
Site 12	15:20	9.5	9:40	6.1	10:20	6.6
Site 13	8:30	4.4	10:20	7.1	11:00	7.2
Site 14	9:40	4.4	11:15	7.7	11:30	--
Site 15	10:00	4.8	11:50	8.2	11:35	8.1
Site 16	10:25	5	15:00	9.1	12:15	8.7
Site 17	10:45	5.4	14:15	8	12:40	9
Site 18	11:15	5.5	13:25	7.4	13:00	9.1
Site 19	11:50	5.3	12:45	6.5	14:35	8.9
Site 20	12:15	4.8	11:10	5.6	13:30	8.7

Table 2. pH data (standard units) on the Fryingpan River on May, June, Oct

Site #	Time	pH Event 1	Time	pH Event 2	Time	pH Event 3
Site 1	14:45	8.49	12:25	8.37	10:00	8.35
Site 2	15:25	8.53	13:40	8.26	11:15	8.37
Site 3	16:15	8.63	14:25	8.41	11:45	8.41
Site 4	9:05	7.82	15:35	8.39	12:00	8.47
Site 5	10:00	8.06	16:05	8.38	12:30	8.55
Site 6	10:50	8.22	9:00	7.81	13:20	8.75
Site 7	12:20	8.62	10:00	7.93	14:05	8.92
Site 8	13:00	8.51	10:40	8.42	14:50	8.92
Site 9	13:30	8.55	16:00	8.54	15:45	8.83
Site 10	14:00	8.68	16:43	8.52	16:25	8.63
Site 11	14:50	8.56	9:05	7.78	9:25	8.18
Site 12	15:20	8.61	9:40	7.96	10:20	8.35
Site 13	8:30	8.19	10:20	8.09	11:00	8.47
Site 14	9:40	7.97	11:15	8.21	11:30	--
Site 15	10:00	8.07	11:50	8.29	11:35	8.56
Site 16	10:25	8.22	15:00	8.43	12:15	8.70
Site 17	10:45	8.18	14:15	8.22	12:40	8.44
Site 18	11:15	8.33	13:25	8.36	13:00	8.59
Site 19	11:50	8.33	12:45	8.23	14:35	8.61
Site 20	12:15	8.3	11:10	7.79	13:30	8.75

Table 3. Specific conductance data (uS/cm) on the Fryingpan River on May, June, Oct

Site #	Time	SC Event 1	Time	SC Event 2	Time	SC Event 3
Site 1	14:45	223.9	12:25	219.2	10:00	226.7
Site 2	15:25	222.9	13:40	218.3	11:15	224.4
Site 3	16:15	222.2	14:25	217.2	11:45	225.5
Site 4	9:05	224.3	15:35	215.6	12:00	220.8
Site 5	10:00	223.5	16:05	215.6	12:30	218.4
Site 6	10:50	226.5	9:00	217.3	13:20	209.1
Site 7	12:20	219.4	10:00	211.9	14:05	206.3
Site 8	13:00	220.1	10:40	208.1	14:50	204.1
Site 9	13:30	214.7	16:00	206.6	15:45	200.6
Site 10	14:00	214.5	16:43	206.6	16:25	200.6
Site 11	14:50	213.2	9:05	205.5	9:25	198.2
Site 12	15:20	212.4	9:40	204.4	10:20	193.9
Site 13	8:30	212.1	10:20	211.4	11:00	196.9
Site 14	9:40	214.6	11:15	200.6	11:30	--
Site 15	10:00	210	11:50	195.1	11:35	185.7
Site 16	10:25	212.8	15:00	196.2	12:15	185.3
Site 17	10:45	214.7	14:15	197.7	12:40	189.5
Site 18	11:15	214.7	13:25	197.1	13:00	187.1
Site 19	11:50	215.2	12:45	197.3	14:35	184.3
Site 20	12:15	204.2	11:10	192.3	13:30	177.4

Table 4. Dissolved oxygen data (mg/L) on the Fryingpan River on May, June, Oct

Site #	Time	DO Event 1	Time	DO Event 2	Time	DO Event 3
Site 1	14:45	--	12:25	11.23	10:00	10.51
Site 2	15:25	--	13:40	11.1	11:15	10.7
Site 3	16:15	--	14:25	10.92	11:45	10.78
Site 4	09:05	--	15:35	10.51	12:00	10.56
Site 5	10:00	--	16:05	11	12:30	10.55
Site 6	10:50	9.78	09:00	--	13:20	10.22
Site 7	12:20	10.68	10:00	11.93	14:05	11.2
Site 8	13:00	10.78	10:40	--	14:50	10.77
Site 9	13:30	9.83	16:00	--	15:45	10.27
Site 10	14:00	9.25	16:43	--	16:25	9.71
Site 11	14:50	9.53	09:05	--	09:25	9.88
Site 12	15:20	8.62	09:40	--	10:20	9.99
Site 13	08:30	9.51	10:20	9.27	11:00	10.27
Site 14	09:40	8.54	11:15	9.21	11:30	--
Site 15	10:00	9.11	11:50	8.23	11:35	9.61
Site 16	10:25	9.62	15:00	--	12:15	10.12
Site 17	10:45	9.24	14:15	--	12:40	9.29
Site 18	11:15	9.37	13:25	9.98	13:00	9.63
Site 19	11:50	9.11	12:45	11.24	14:35	10.08
Site 20	12:15	8.51	11:10	12.08	13:30	11.27

Table 5. Didymo (grams/square inch) and total organic carbon on the Fryingpan River in June

Site #	TOC %	Weight/area
Site 1	3.24	0.045
Site 2	4.73	0.041
Site 3	6.74	0.030
Site 4	7.14	0.011
Site 5	4.09	0.049
Site 6	4.62	0.056
Site 7	5.13	0.043
Site 8	13.52	0.183
Site 9	10.90	0.102
Site 10	8.72	0.158
Site 11	14.22	0.100
Site 12	5.06	0.081
Site 13	9.32	0.098
Site 14	11.32	0.198
Site 15	11.36	0.102
Site 16	7.22	0.101
Site 17	10.44	0.122
Site 18	9.58	0.078
Site 19	20.31	0.123
Site 20	15.56	0.178